Leo Miller, Technology Insertion Project Officer (TIPO)
US Army National Automotive Center (NAC) Warren, MI

NAC Aftermarket Brake Components Project

(Secondary Items)

Version: 06 February 2007 Final

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U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
06 FEB 2007	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
NAC Aftermarket Brake Components Project	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Miller, Leo	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
US ARMY TACOM 6501 E 11 Mile Road Warren, MI 48397-5000	**16964**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	TACOM TARDEC
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
	16964

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**24**	

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Supporting the Objective Force –

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"To Promote Full-and-Open Competition"

Internal Tasker by NAC Director: "Fix" sole-source brake component issues on HMMWV-ECV based on contractor and Congressional complaints.

Objectives established 4Q FY05: Reduce O&S burdens by establishing cost-effective, off-vehicle brake component testing to establish a viable process for submittal of alternative items or R&D efforts.

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- All potential stakeholders identified; established formal working relationships with other Services, industry experts, and Standards Determining Organizations (SDO) up-front and early.

- Overarching Federal statutory, SDO (e.g. SAE, ISO), and similar civilian standards basically non-existent for aftermarket brake components; lots of smaller pieces, but no controlling documents.

- Traditional (military) program tools used to identify scope, range, impacts, and opportunities to include innovative solutions to address roadblocks; needed sound business model to support cost-recovery and anticipated cost avoidance over system life cycle .

- Not intended to be “pass-or-fail” documents; vehicle system engineer retains full approval authority - testers/buyers can’t make decision!

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- **Project would NOT be constrained by FMVSS or ISO/military GVW issues, 10K and 12K respectively, or hydraulic versus air-actuation in SDO specs, but then reality set in…...**

- **Initial project output will be locally-managed "ATPD", followed by new Federal Test Standard (MIL-STD); forms basis for SAE or TMC Recommended Practice (RP) and/or follow-on ISO.**

- **Industry and SDO participation critical due to historical lack of Government in-house expertise.**

- **TARDEC (Other), "TACOM" PEO/PM, DSCC (DLA-Columbus), USAF, USMC, and Aberdeen (DTC) must be active and cooperative players.**

- **Project originally unfunded effort which, when Government funds became available, was forced to actually delay development/release!**

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Innovative and original approaches taken by team.

- **Create a methodology and submittal process that's not "pass-or-fail", where the vehicle system engineer (only) retains full approval authority; test activities, testers, and acquisition can't make decision.**

- **Create a compilation of existing specs & standards, with development only for those tests not readily available in the public domain, using OEM "average" performance as baseline suitable for all phases of Life Cycle Management and Life Cycle Cost Management (LCM/LCCM).**

- **Create "apples-to-apples" comparison testing processes, and require project outputs documents to be proofed by actual independent testing; HMMWV-ECV (disc) and HEMTT "ESS" (drum) as targeted systems.**

- **With LINK's permission, use their copyrighted test procedures in ATPD due to the lack of existing specs; e.g. replicate TOP 2-2-608.**

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Innovative and original approaches taken by team. (cont.)

- **Project was reduced in scope to pads/rotors and drums/brake shoes to reduce complexity and program risks.**

- **"Mandatory" shall be minimum acceptable for a reasoned decision by the cognizant "ESA" to accept or reject alternative items!**

- **Test Methods use brake/hub-end ratings (not axle ratings), or ESA-designated "overload" conditions, or conditions specific to R&D.**

- **Established realistic cost projections and business modeling early. ("air" costs more than "hydraulics" overall)**

• **"Mandatory" test estimated $45-50K plus parts/fixturing.**

• **Estimated $70K highest total for "first time effort".**

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1. Characterization of GVBS by vehicle models/types/OEMs.

2. Characterization of OEM (or approved designated similar) Components through standardized testing.

3. Characterizations of Proposed Replacement Components through standardized testing.

4. Characterization of Proposed Replacement Components When Mixed With OEM through standardized testing.

5. Compile and Conduct Comparative Analysis of results to support Suitability Determination by external customer.

6. Post-test Suitability Determination for Proposed Use by each vehicle type/model by external customer.

- **Method "A" Process/Procedure (aka "standard").**
- **Method "B" Procedure (a.k.a. "overload").**
- **Method "C" Procedure (a.k.a. "commercial/non-tactical").***
- **Method "D" Procedure (a.k.a. "R&D Only").**

1. Method "A", "B" and Method "C" all have same processes plus OEM hub-end hardware for fixturing; Method "D" is R&D only.
2. All military and any independent suspension axles/hub-ends must use actual brake/hub-end ratings by OEM or "ESA".
3. "Wet" steering/brakes effort may be developed by CRADA only.
4. (*) Retained as placeholder only; not cost-effective.

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- **Method "A" Process/Procedure (aka "standard"): primarily for secondary items (spare parts); also suitable for development work like drum to disc or S-cam to Wedge.**

- **Method "B" Procedure (a.k.a. "overload"). Probably unique to military; e.g. up-armored vehicles recently developed.**

- **Method "C" Procedure (a.k.a. "commercial/non-tactical").* "Reserved" spot only; Method "A" is cheaper and better overall despite anticipated perception it's too rugged.**

- **Method "D" Procedure (a.k.a. "R&D Only"). Self-explanatory; developmental and future systems where specific suspension and hub-end hardware is yet to be finalized.**

"Test Plans"

- Five (5) basic areas covered for "dry" brakes:
- Dimensional, physical, and materials if applicable
- Friction characterization +, for pad and shoe assemblies
  or
- Fatigue & crack testing +, for rotor and drum assemblies
- Performance, wear, and noise (aka Laurel Mt. & Jennerstown)
- Test sample quantities/assignments: some restrictions apply.

"Test Plans" continued:

- **Unique, previously proprietary, and/or new testing procedures:**
  - Laurel Mountain/Jennerstown (re: Army TOP 2-2-608)
  - Slope/Hill-hold (re: military 60% vs. 20% civilian)
  - "Fatigue & Crack" testing for rotors and drums (ECE/LINK/or ?)
  - Wet effectiveness test (re: FMVSS requirements)
  - If/when developed, wet steering/brakes will use various commercial SAE, ISO, and/or OEM-specific specs with similar approach as the "dry" brakes.
  - Will dictate "manual" adjusters due to known issues.

1. Appendix A. Definitions (continued).
2. Appendix B. Test Plans and Sample Assignments for Disc Brake Pads and (Foundation) Drum Brake Shoes.
3. Appendix C. Test Plans and Sample Assignments for Disc Brake Rotors and Drum Brake Drums.
4. Appendix D. Off-vehicle Inertia Dynamometer Test Procedures.
5. Appendix E. “Crack & Fatigue” Tests for rotors and drums.
6. Appendix F. Inertia-dynamometer testing mathematical calculations and equations.
7. Appendix G. Flow chart describing methodology required to initially approach Government through submittal for approval.

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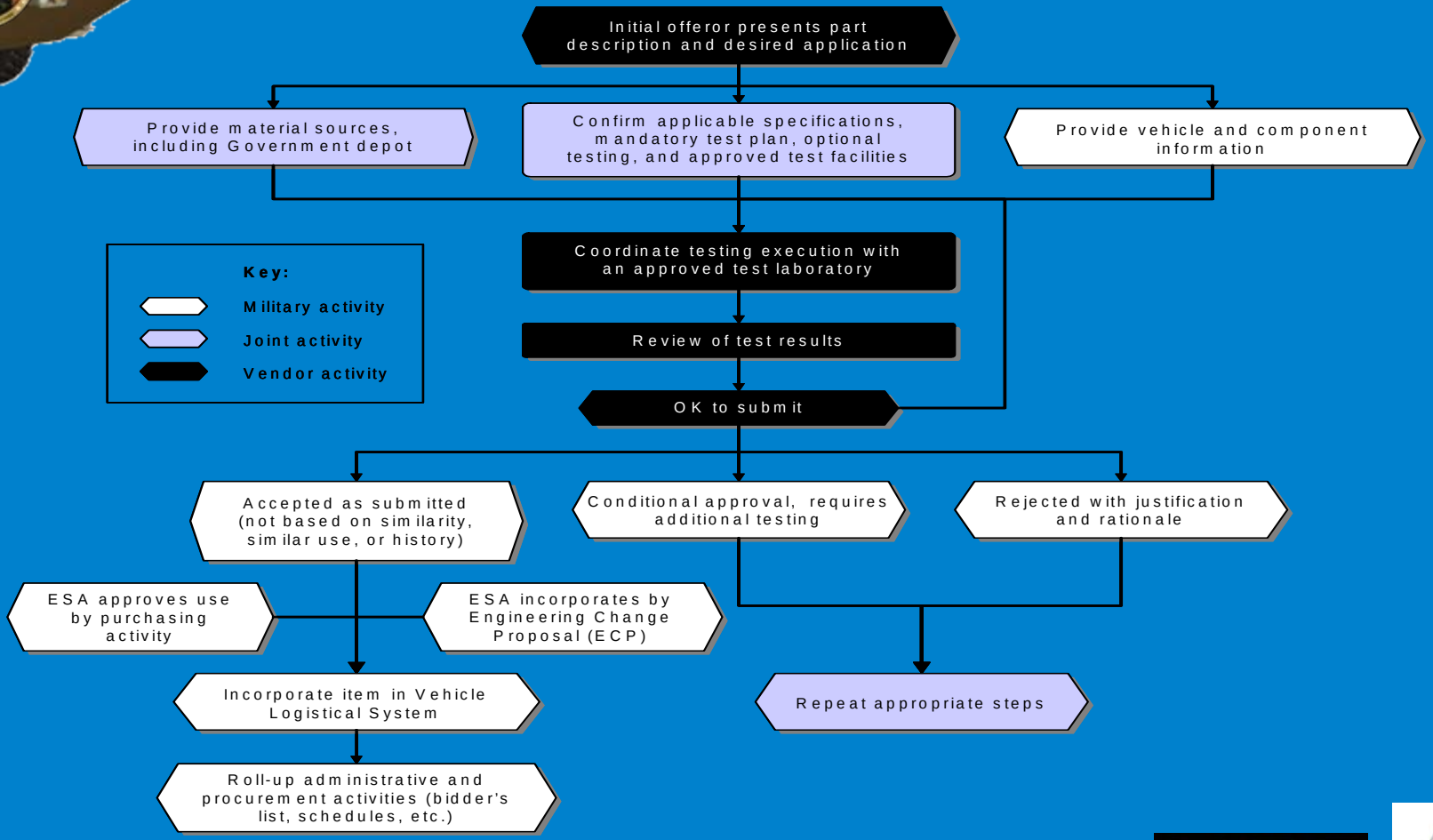

THE MOST IMPORTANT CHART!

Project Status (January 2007)

- **Verification testing funded and scheduled; testing will be concurrent and/or overlapping to offset delays due to parts problems.**
- **Plan release ATPD-2354 to DLA and TACOM after Final Test Report approval (late April - early May); formal MIL-SPEC later.**
- **Two (2) SAE Papers co-authored by Agudelo & Miller; potential collaboration with SAE-Automotive on friction materials (only).**
- **Companion verbal presentations at SAE World Brake Congress (TX), Oct 06; SAE Truck & Bus ComVec, Nov 06.**
- **TMC/ATA update brief under CRADA effort, Feb 07.**
- **SAE T&B Brake Committee brief on final product, Apr-May 07**

TACOM, TARDEC, and PEO/PM Players (01 Jan 06)

- Director, USA National Automotive Center (NAC)
- Chief, TACOM Safety Office (System Safety/Compliance)
- TACOM Packaging (PPS Engineering)
- Team Leader, TARDEC-EBG (Specs & Standards)
- TARDEC- EBG Legacy Vehicle Engineering Support (All)
- PM-HTV (Heavy Truck Engineering)
- PM-MTV (FMTV/Medium Vehicle Engineering plus ASV)
- PM-LTV (HMMWV/Light Vehicle Engineering)
- PM-CCE (CE Support Team Leader)
- TACOM Competition Advocates Office
- PEO CS & CSS (New Products/Technology Insertion)
- PEO-GCS, Tracked Vehicles (Note: Withdrew Jan 07)
- PM-Stryker, Engineering Support
- TARDEC-DLA Liaison, TARDEC-EBG

Other Government and Industry Players (01 Oct 06)

- Developmental Test Command (DTC)-Aberdeen: Heavy, Medium, and Light Wheeled Vehicle POC's
- USAF- WRAFB, GA
- USAF TARDEC LNO, TARDEC-Warren
- DLA-Columbus (DSCC) to TARDEC LNO
- LINK Testing Laboratories, Detroit, MI (2005 CRADA)
- SAE-Troy (2006 LOA)
- SAE T&B Brake Committees
- TMC/ATA (2006 CRADA Mod)
- SAE Automotive equivalents - pending
- YOUR NAME HERE?

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ITEM	ATPD 2354 (MIL-SPEC) Test Plan TYPE OF TEST Disc pads and brake shoes	Hydraulic Air/Both	Standard/Test procedure
	PHYSICAL & DIMENSIONAL PROPERTIES		
1	Material Identification/Certifications - as required when identified by requirement, specification, drawing, or purchase order.	both	CoC/Lab Results
2	Visual inspection	both	**TBD (ISO CD 22574)**
3	Critical dimensions verifications	both	STM
4	Shear strength adhesion/bonding (-40 ^{o}C)	hydraulic	SAE J840 (ISO 6312)
5	Shear strength adhesion/bonding (750 ^{o}F) (400 ^{o}C)	hydraulic	SAE J840 (ISO 6312)
6	Compressibility, ambient	both	SAE J2468 (ISO 6310)
7	Compressibility, elevated temperature	both	SAE J2468 (ISO 6310)
8	Brinell Hardness on metallic parts (rotor, drum, shoe, backing plate)	both	ASTM E 10
9	Thermal swell and growth	both	SAE J160
	INERTIA-DYNAMOMETER FRICTION COUPLE PERFORMANCE AND DURABILITY		
10	Friction Behavior and Performance Assessment Hydraulic Brakes single-ended; with front/rear balance assessment (up to V_{max})	hydraulic	SAE J2522 **(ISO NWI 2560)**
11	Friction Behavior and Performance Assessment Air Brakes single-ended; with front/rear balance assessment	air	SAE J2115
12	Friction Behavior and Performance Assessment Hydraulic Brakes dual-ended left/right (up to V_{max})	hydraulic	SAE J2522 **(ISO NWI 2560)**
13	Friction Behavior and Performance Assessment Air Brakes dual-ended left/right	air	SAE J2115
14	Jennerstown Fade Dyno test with noise	both	Link W05065LINKA-C1©
15	Wear and durability (Laurel Mountain 4 Cross-Country cycles) with noise	both	Link W05065LINKA-C1©

Proposed Mandatory Testing Plan Pads and Shoes (April 2006)

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ITEM	ATPD 2354 (MIL-SPEC) Test Plan TYPE OF TEST Disc pads and brake shoes	Hydraulic/Air/Both	Standard/Test procedure	SAMPLE ASSIGNMENT				
				HYDRAULIC		AIR		
				Test pad number baseline (A)	Test pad number candidate (B)	Test shoe number baseline (A)	Test shoe number candidate (B)	ROTOR/ DRUM
	PHYSICAL & DIMENSIONAL PROPERTIES							
1	Material Identification/Certifications - as required when identified by requirement, specification, drawing, or purchase order.	both	CoC/Lab Results	N/A	N/A	N/A	N/A	N/A
2	Visual inspection	both	**TBD (ISO CD 22574)**	All A	All B	All A	All B	
3	Critical dimensions verifications	both	STM	All A	All B	All A	All B	
4	Shear strength adhesion/bonding (-40 °C)	hydraulic	SAE J840 (ISO 6312)	1-3A	1-3B			
5	Shear strength adhesion/bonding (750 °F) (400 °C)	hydraulic	SAE J840 (ISO 6312)	4-6A	4-6B			
6	Compressibility, ambient	both	SAE J2468 (ISO 6310)	7-9A	7-9B	1-3A	1-3B	
7	Compressibility, elevated temperature	both	SAE J2468 (ISO 6310)	7-9A	7-9B	1-3A	1-3B	
8	Brinell Hardness on metallic parts (rotor, drum, shoe, backing plate)	both	ASTM E 10	7-9A	7-9B	1-3A	1-3B	
9	Thermal swell and growth	both	SAE J160	10-12A	10-12B	3-4A	3-4B	
	INERTIA-DYNAMOMETER FRICTION COUPLE PERFORMANCE AND DURABILITY							
10	Friction Behavior and Performance Assessment Hydraulic Brakes single-ended; with front/rear balance assessment (up to V_{max})	hydraulic	SAE J2522 **(ISO NWI 2560)**	12-17A	12-17B			1-6C
11	Friction Behavior and Performance Assessment Air Brakes single-ended; with front/rear balance assessment	air	SAE J2115			5-10A	5-10B	1-6C
12	Friction Behavior and Performance Assessment Hydraulic Brakes dual-ended left/right (up to V_{max})	hydraulic	SAE J2522 **(ISO NWI 2560)**	18-23A	18-23B			7-12C
13	Friction Behavior and Performance Assessment Air Brakes dual-ended left/right	air	SAE J2115			11-16A	11-16B	7-12C
14	Jennerstown Fade Dyno test with noise	both	Link W05065LINKA-C1©	24-29A	24-29B	17-22A	17-22B	13-18C
15	Wear and durability (Laurel Mountain 4 Cross-Country cycles) with noise	both	Link W05065LINKA-C1©	24-29A	24-29B	17-22A	17-22B	13-18C
	Total number of test samples submitted by axle sets			**10**	**10**	**8**	**8**	**12**

Proposed Mandatory Test Sample Distribution Friction (April 2006)

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ITEM	ATPD 2354 (MIL-SPEC) Test Plan TYPE OF TEST Brake rotors and drums	Hydraulic Air/Both	Standard/Test procedure
	PHYSICAL & DIMENSIONAL PROPERTIES		
1	Material Identification/Certifications - as required when identified by requirement, specification, drawing, or purchase order.	both	CoC/Lab Results
2	Visual inspection	both	STM
3	Critical dimensions verifications	both	STM
4	Brinell Hardness	both	**ASTM E 10**
5	Lateral/radial Run-Out; DTV measurement (rotors only)	both	STM
	INERTIA-DYNAMOMETER ROTOR/DRUM PHYSICAL PERFORMANCE		
6	Disc and Drum crack and strength test	both	Link W05036LINKB-D0© **(SAE J2686 drum)** **(ECE R90 rotors/drums)**
	INERTIA-DYNAMOMETER FRICTION COUPLE PERFORMANCE AND DURABILITY		
7	Friction Behavior and Performance Assessment Hydraulic Brakes single-ended; with front/rear balance assessment (up to V_{max})	hydraulic	SAE J2522 **(ISO NWI 2560)**
8	Friction Behavior and Performance Assessment Air Brakes single-ended; with front/rear balance assessment	air	SAE J2115
9	Jennerstown Fade Dyno test with noise	both	Link W05065LINKA-C1©
10	Wear and durability (Laurel Mountain 4 Cross-Country cycles) with noise	both	Link W05065LINKA-C1©

Proposed Mandatory Testing Plan Rotors and Drums (April 2006)

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ITEM	ATPD 2354 (MIL-SPEC) Test Plan TYPE OF TEST Brake rotors and drums	Hydraulic Air/Both	Standard/Test procedure	SAMPLE ASSIGNMENT				
				HYDRAULIC		AIR		
				Rotor/Drum number baseline (A)	Rotor/Drum number baseline (B)	Rotor/Drum number baseline (A)	Rotor/Drum number baseline (B)	Pad/Shoe number
	PHYSICAL & DIMENSIONAL PROPERTIES							
1	Material Identification/Certifications - as required when identified by requirement, specification, drawing, or purchase order.	both	CoC/Lab Results	N/A	N/A	N/A	N/A	N/A
2	Visual inspection	both	STM	All A	All B	All A	All B	
3	Critical dimensions verifications	both	STM	All A	All B	All A	All B	
4	Brinell Hardness	both	**ASTM E 10**	1-3A	1-3B	1-3A	1-3B	
5	Lateral/radial Run-Out; DTV measurement (rotors only)	both	STM	1-3A	1-3B	1-3A	1-3B	
	INERTIA-DYNAMOMETER ROTOR/DRUM PHYSICAL PERFORMANCE							
6	Disc and Drum crack and strength test	both	Link W05036LINKB-D0© **(SAE J2686 drum)** **(ECE R90 rotors/drums)**	1-3A	1-3B	1-3A	1-3B	As required
	INERTIA-DYNAMOMETER FRICTION COUPLE PERFORMANCE AND DURABILITY							
7	Friction Behavior and Performance Assessment Hydraulic Brakes single-ended; with front/rear balance assessment (up to V_{max})	hydraulic	SAE J2522 **(ISO NWI 2560)**	4-6A	4-6B			1-6C
8	Friction Behavior and Performance Assessment Air Brakes single-ended; with front/rear balance assessment	air	SAE J2115			4-6A	4-6B	1-6C
9	Jennerstown Fade Dyno test with noise	both	Link W05065LINKA-C1©	7-9A	7-9B	7-9A	7-9B	7-18C
10	Wear and durability (Laurel Mountain 4 Cross-Country cycles) with noise	both	Link W05065LINKA-C1©	7-9A	7-9B	7-9A	7-9B	7-18C
	Total number of test samples submitted by axle sets			**6**	**6**	**6**	**6**	**15**

Proposed Mandatory Test Sample Distribution Rotors/Drums (April 2006) Backup Slide 4 of 8

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What's an ESA ? (Short version!)

- The inclusive term "ESA" (Engineering Support Activity) shall be defined as the responsible Army vehicle system engineering authority, equivalent non-Army Governmental vehicle design authority, or non-US Governmental civilian engineering activity's designated vehicle or brake program engineer when used solely as a commercial/civilian undertaking. This definition may also include civilian commercial fleet owners or their designated surrogates when subject specification is used as a decision support tool for the specific brake replacement items covered by subject specification.

- DOD procurement offices/activities, other Government and quasi-Government procurement offices/activities, civilian/commercial buying offices/activities, and other similar non-engineering functions are specifically excluded from this definition as they do not have the vehicle system engineering expertise and/or legal approval authority required for brake systems and their subcomponents.

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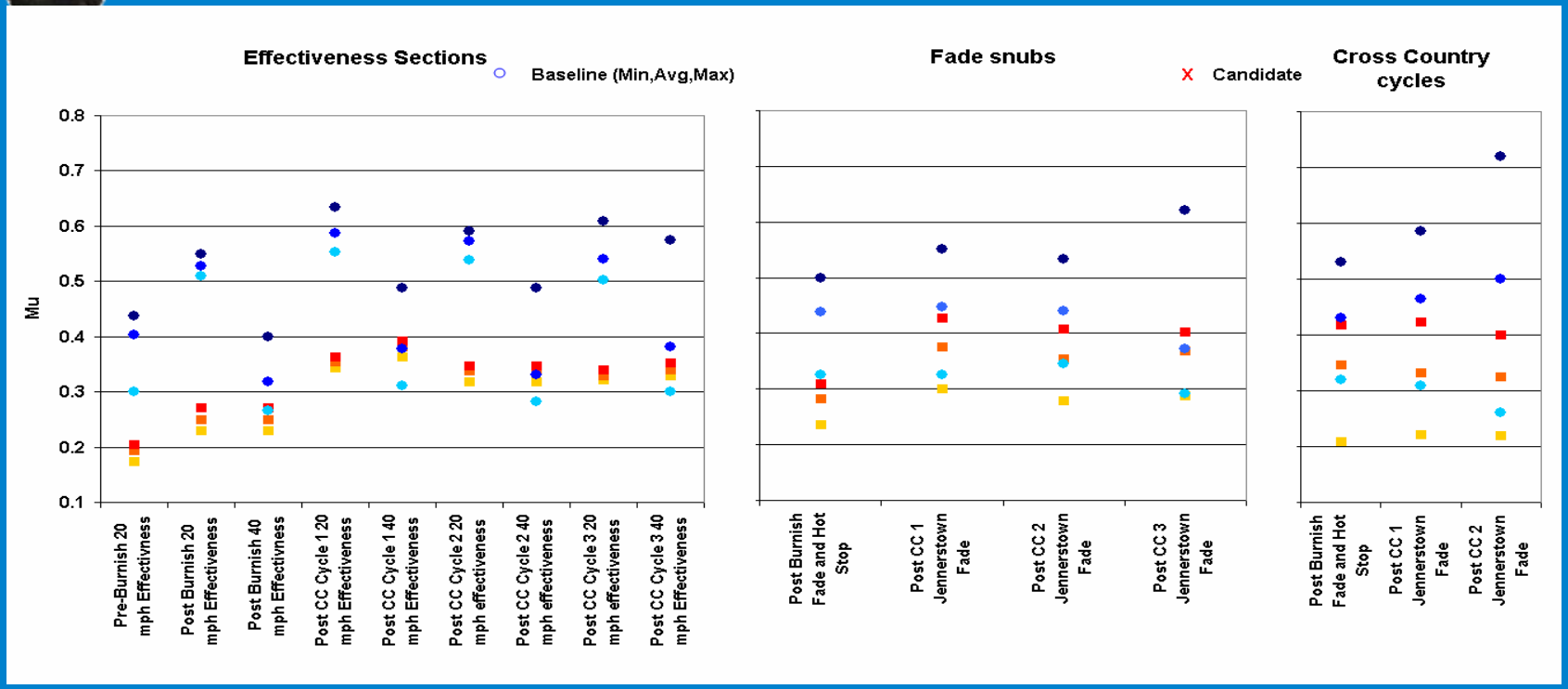

Friction behavior: TOP 2-2-608 inertia-dynamometer simulation (3 c/c cycles).

NOTE: A second "candidate" material did not survive the test.

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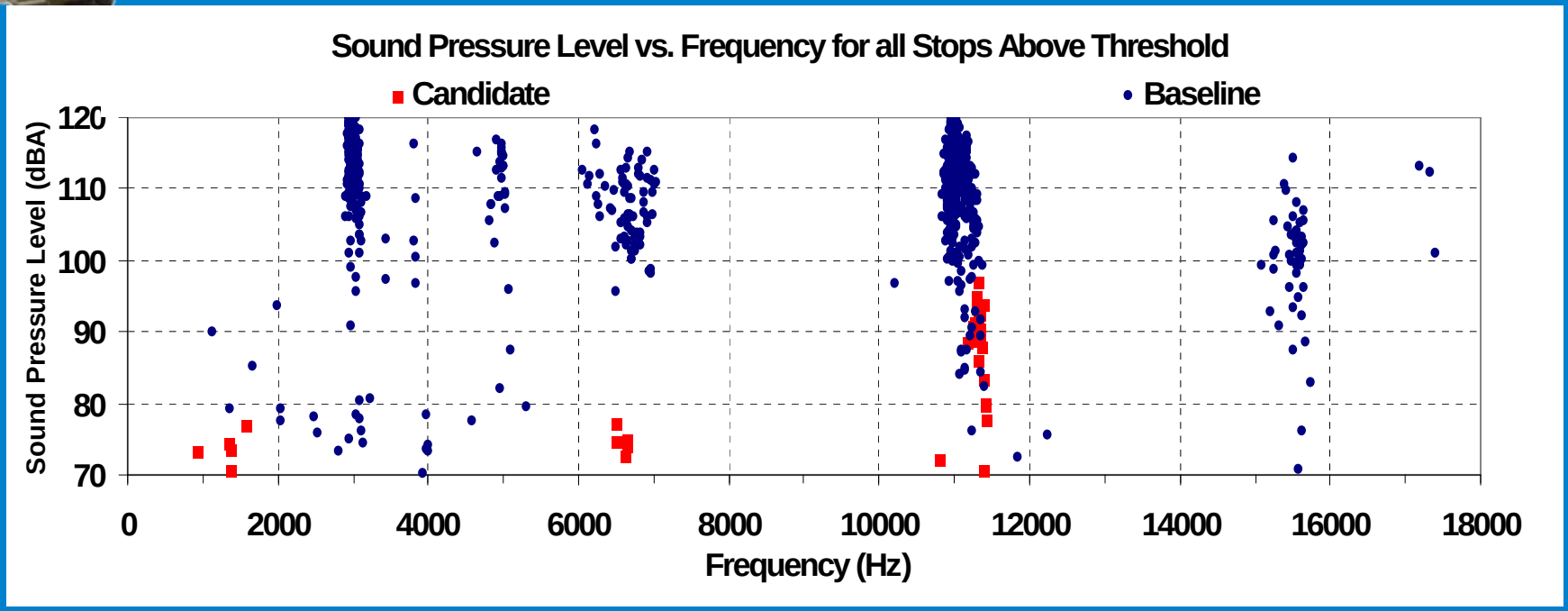

Noise level behavior: TOP 2-2-608 inertia-dynamometer simulation.

(3 cross-country)

NOTE: A second "candidate" material did not survive the test.

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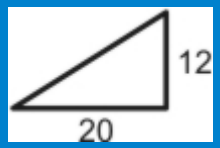
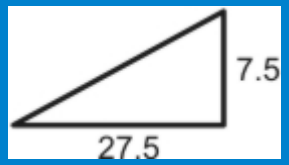
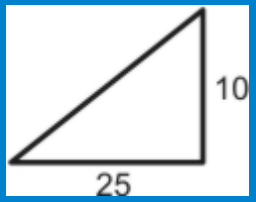
Some possible examples to use are shown below:



Percent Slope = 60%



Percent Slope = 27.3%



Percent Slope = 40%

Computing percent slope is demonstrated by the examples above.
Note: May be expressed as a “super-elevation” (± grade).

Vertical Leg (Rise)/Horizontal Leg (Run) X 90 = Slope (%)

Also use charts in US Army TM 5-236, Surveying Tables and Graphs, C1, 13 May 1957.

Slope/incline versus Angle Instructional Slide

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